International Journal of Environment, Ecology, Family and Urban Studies (IJEEFUS)
ISSN(P): 2250-0065; ISSN(E): 2321-0109
Vol. 6, Issue 1, Feb 2016, 135-150

TRANS STELLAR
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ASSESMENT OF WATER QUALITY INDEX FOR GROUND WATER OF INDUSTRIALIZED AREA OF SURAT CITY, GUJARAT, INDIA

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ABSTRACT

Assessment of water quality index for ground water of industrialized area of Surat city, Gujarat, India have been done by calculating Water quality Index value. The physicochemical analysis of 09 ground water samples namely Pandesara housing colony, Pandesara gam, Bhatpor, Bhestan, Udhna Gam., Limbayat, Damka, Sachin GIDC, Sachin gam were done by using APHA standard methods of analysis. The results of the analysis when compared with desirable limits of Indian standards for Drinking Water (IS: 10500.1993), in all the 09 sampling stations, most of the selected water quality parameters were observed above desirable limit. The WQI values of 09 ground water samples located nearer to industrialized area were found in the range of 179.82-1257.2 in winter season, 219.2-1290.11 in summer season, 167.42-1244.6 in post monsoon season. Based on average value of WQI, highest WQI was found in ground water sample of Udhna Gam (1263.97). Udhna Gam is very nearer to the Udhna GIDC (which are having 700 large scale and 6000 small scale industries of textile, chemical, pharmaceutical and metal industries) and the Udhna Khadi is 1.0-1.5 km away from the sampling point into which effluents of industries are discharged. The higher values of WQI was found (for all 09 ground water samples) in summer season may be due to the lowering of water table, while the values of WQI in winter and post monsoon season is comparatively lower due to recharging of bore wells in the rainy season. All 09 ground water samples of industrialized area were having high WQI values, from these results, it is concluded that none of the studied 09 sources can be used for drinking, domestic or for industrial purposes.

KEYWORDS: Water Quality Index

Received: Jan 13, 2016; **Accepted:** Jan 20, 2016; **Published:** Feb 03, 2016; **Paper Id.:** IJEEFUSFEB201614

Original Article

INTRODUCTION

Water is essential to all forms of life and makes up 50-97% of the weight of all plants and animals and about 70% of human body. Groundwater is ultimate and most essential suitable fresh water resources for human consumption in both urban as well as rural areas. There are several states in India where more than 90% population is dependent on groundwater for drinking and other purposes. Groundwater is a source used for agricultural and industrial purposes now a day. In recent years, an increasing threat to groundwater quality due to human activities has become of great importance. The ground water pollution occur due to the over burden of the population pressure, unplanned urbanization and unrestricted exploration, discharge of domestic, agriculture and industrial effluents and discharge of the polluted water at inappropriate place which enhance the infiltration of harmful compounds to the groundwater. The increasing demand of water from fast growth of industries has put pressure on limited water resources. Water quality analysis is one of the most important aspects in groundwater studies. [1] So, this work includes evaluation of selected physicochemical parameters of groundwater especially nearer to industrial area of Surat city, Gujarat, India and to find out WQI value to check suitability for drinking,

industrial and domestic purposes of such ground water.

Study Area: Surat is Located in the Southern part of Gujarat. Geographical Location: 72.38° to 74.23 ° East (Longitude), 21.0 to 21.23 ° North (Latitude). **Surat** is the **second largest** commercial hub in the State. **Surat** is mainly known for its **textiles, diamond processing and petrochemical industries.** The biggest industrial zone of city is Udhna GIDC, Pandesa GIDC and the Sachin GIDC. Mainly these GIDCs having the textile, dimond, chemical, rubber and the metal industries. The other biggest industrial zone of Surat city is the Hazira which involves the production of naphtha, motor spirit, diesel, LPG, LPG equipment, chlorine, propene, marcaptan, benzene, ehthylene, liquid oxygen, argon, high speed diesel, ammonia, etc. [2] There are over 41,300 small scale industries (SSI) functioning in Surat district. Some of the main industries under SSIs in Surat are textiles, chemicals dying & printing, diamond processing, jhari (Silver) making, and. engineering and related activities (manufacturing machineries & equipments).

Sampling and Methodology

The Ground water quality has been checked into the area which is located nearer to the industrial zone to check the pot ability of the ground water for drinking purpose. The name of the sampling stations are Pandesara housing colony, Pandesara gam, Bhatpor, Bhestan, Udhna Gam., Limbayat, Damka, Sachin GIDC, Sachin gam. As here samples were well water, the pumps had been run long enough (15 min) to draw fresh groundwater into the system and from the depth of 35-40 feet and samples were collected. All the ground water samples were collected from bore well sources in winter, summer and post monsoon seasons. Each season consist of 4 months. 4 times sampling from the same source point was done and each analysis was done for 3-4 times to get concordant reading. In each season more or less the value of parameter was obtained similar. Here constant value is shown for each season. The parameters were analyzed as per the Standard Methods for the Examination of Water and Waste water, 21st Edition, (2005) [APHA methods]. [3]

RESULT AND DISCUSSIONS

The results of selected parameters were compared with standard for drinking water, given by Indian standards, shown in **Table 1.** [4] We have considered IS: 10500 required desirable limit for observed outside the desirable limit.drinking water and have not considered IS: 10500 Permissible limits due to Undesirable effect.

Table 1: Comparison of Results of Different Parameters of 09 Sampling Stations of Indistrial Area with Indian Standard Specification for Drinking Water (IS: 10500), 1993

Water Quality Parameters	Desirable Limit	Year 2012	Pandesa Colony	Pandesar Gam	Bhatpor	Bhestan	Udhna Gam	Limbayat	Damka	Sachin GIDC	Sachin Gam
pH	**7.5-8.5**	winter	7.4	7.3	7.7	7.5	7.6	7.2	8	7.6	7.8
		summer	7.5	7.33	7.81	7.6	7.8	7.25	8.28	7.69	7.84
		Post monsoon	7.4	7.2	7.6	7.49	7.5	7.18	7.8	7.59	7.79
DO	**7**	winter	4.2	4.3	4.1	7.4	3.2	5.5	6.6	5.2	5.4
		summer	3.9	4	3.9	7.3	2.9	5.4	6.4	5	5.3
		Post monsoon	4.29	4.4	4.12	7.8	3.28	5.8	6.9	5.23	5.5
COD	**10**	winter	295	150	100	150	410	186	210	325	280
		summer	340	160	120	180	420	200	240	360	300
		Post monsoon	290	140	90	130	390	180	189	315	272
TSS	**100**	winter	200	125	120	290	400	172	89	192	700
		summer	350	225	125.92	292.75	418	175	95	195	725
		Post monsoon	190	120	105	275	395	170	83	191	692
TDS	**1000**	winter	2500	1000	945	1090	4200	820	710	1000	2700
		summer	2620	1200	950	1100	4249.23	825	725	1075	2795
		Post monsoon	2425	990	920	1050	4115	815	708	995	2690
EC	**0.75**	winter	5.6	3	1.1	5.9	5.59	1.1	2.18	3.39	6.8

Table 1: Contd.,											
		summer	5.9	3.2	1.2	6.1	5.6	1.1	2.2	3.4	6.9
		Post monsoon	5.5	2.29	0.99	5.89	5.49	0.9	2.15	3.38	6.79
Salinity	**1**	winter	2.4	1.1	0.3	3.1	2.6	0.49	1.1	1.7	3.4
		summer	2.5	1.2	0.5	3.2	2.7	0.4	1.2	1.7	3.4
		Post monsoon	2.39	1.1	0.3	3	2.5	0.45	1.09	1.69	3.33
Total Hardness	**300**	winter	1100	500	550	900	1339	495	650	515	1180
		summer	1260	580	570	1050	1400	500	660	520	1200
		Post monsoon	1090	480	545	895	1300	490	640	510	1100
Ca Hardness	**75**	winter	400	140	120	390	242	160	190	180	270
		summer	450	210	130	400	250	170	200	190	290
		Post monsoon	350	130	118	380	235	155	180	175	260
Mg Hardness	**30**	winter	700	360	430	510	1091	335	480	335	910
		summer	810	370	440	650	1150	330	460	330	910
		Post monsoon	840	350	327	515	1065	235	460	335	840
Copper	**0.05**	winter	6.1	2.3	3.7	6.6	93.2	2.8	4.3	4.6	7.1
		summer	6.32	2.38	3.78	6.73	95.31	2.98	4.41	4.76	7.37
		Post monsoon	5.59	2.25	3.6	6.43	93	2.79	4.25	4.5	7.06
Zinc	**5**	winter	5.5	1.2	6.7	1.2	192	7.59	6.88	5.89	1.55
		summer	6	1.6	6.8	1.22	195	7.6	6.9	5.9	1.6
		Post monsoon	5.3	1.18	6.68	1.1	191	7.55	6.7	5.87	1.5
Iron	**0.3**	winter	0.7	0.08	0.083	0.06	0.2	0.08	`0.079	0.79	0.089
		summer	0.82	0.88	0.089	0.07	0.25	0.088	0.089	0.8	0.1
		Post monsoon	0.7	0.079	0.07	0.04	0.15	0.079	0.7	0.7	0.06
Sodium	**200**	winter	118	109	121	70	240	112	111	92	92
		summer	120	115	122	75	250	118	114	100	95
		Post monsoon	112	104	120	69	210	102	99	87	86
Potassium	**12**	winter	48	43	53	39	48	52	56	43	48
		summer	50	45	55	40	52	56	57	53	49
		Post monsoon	47	39	45	38	47	46	53	41	42
Ammonia	**0.001**	winter	0.05	0.02	0.03	0.03	0.05	0.03	0.04	0.04	0.05
		summer	0.08	0.04	0.045	0.046	0.08	0.05	0.059	0.049	0.06
		Post monsoon	0.049	0.015	0.025	0.021	0.048	0.029	0.039	0.039	0.045
Boron	**1**	winter	6.7	5.7	7.3	6.6	7	5.8	7.7	7.7	5.8
		summer	6.9	6	7.4	7	7.2	6	8.2	8	6
		Post monsoon	6.6	5.5	7	6	6.8	5.7	7.7	7.69	5.9
Silica	**14**	winter	45	42	90	95	59	132	90	95	90
		summer	138	132	98	120	60	148	100	104	100
		Post monsoon	40	38	70	90	50	120	86	92	82
Turbidity	**5**	winter	1	1.3	1	0.89	2.8	2.6	2.2	2.1	2.3
		summer	1.1	1.3	1	0.9	2.9	2.6	2.2	2.1	2.5
		Post monsoon	0.98	1.2	0.99	0.87	2.79	2.5	2.18	2.08	2.29
Phenol	**0.001**	winter	0.8	0	0.48	2.2	3.49	2.4	0	0	0
		summer	1.02	0	0.49	2.3	3.6	2.48	0	0	0
		Post monsoon	0.8	0	0.4	2.1	3.5	2.38	0	0	0
Cl	**250**	winter	1000	290.88	160	870	1400	115.5	250	380	1125
		summer	1104.7	499.88	164.96	889.7	1419.57	119.91	259.94	389.91	1149.7
		Post monsoon	900	280	155	850	1329	110	249.6	379	1120
Flouride	**1.2**	winter	1.01	0.18	0.7	0.6	1.5	0.89	0.7	0.69	1.01
		summer	1.02	0.2	0.79	0.7	1.6	0.96	0.79	0.7	1.02
		Post monsoon	1	0.1	0.6	0.59	1.45	0.87	0.69	0.65	1
Sulphate	**200**	winter	83	80	77	60	84	86	70	68	65
		summer	89	83	81	68	90	89	80	70	69
		Post monsoon	78	73	70	55	78	80	74	66	59
Phosphate	**0.02**	winter	0.49	0.5	0.6	0.59	0.4	0.49	0.56	0.59	0.5
		summer	0.52	0.5	0.69	0.6	0.6	0.6	0.6	0.7	0.59
		Post monsoon	0.47	0.48	0.59	0.49	0.33	0.4	0.52	0.58	0.49
MPN	**0**	winter	115	107	38	22	124	122	40	120	98
		summer	120	110	40	25	125	123	42	122	100
		Post monsoon	114	106	33	20	122	118	39	120	97

pH: The variation in pH data for all the studied 09 sampling stations is shown in figure 1. The range of desirable limit for pH of water prescribed for drinking purpose by IS: 10500 are 6.5-8.5 and the pH of analyzed ground water samples is within the limit. The pH values of all studied 09 ground water samples were varied from 7.2-8.0 in winter season, 7.25-8.28 in summer season and 7.18-7.8 in post monsoon season indicating the slightly alkaline nature of selected ground water samples. There is no much variation in pH of different wells which indicates the ground water is tapping from aquifers of a single formation for each individual route. [5, 6]

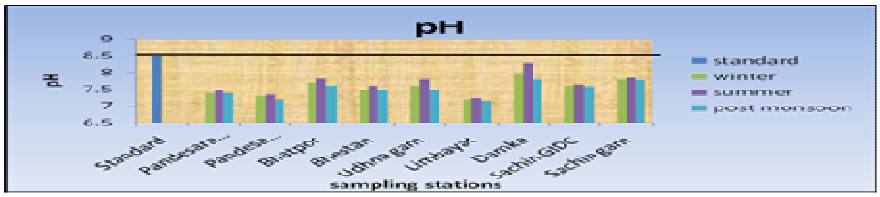

Figure 1: Graphical Representation for pH in Ground Water Samples

Dissolved Oxygen

The variation in DO data for all the studied 09 sampling stations is shown in figure 2. Twelve parts per million (12 mg/L) is the highest amount of oxygen that can be dissolved in water under standard barometric pressures (sea level), 12 mg/L is known as the **saturation point**. [7] Zero parts per million (0 mg/L) is the lowest amount of dissolved oxygen in water. In drinking water 7 mg/l of DO should be present minimum. DO of all studied 09 ground water samples was in the range of 3.2-7.4 mg/l in winter season, 2.9-7.3 mg/l in summer season and 3.38-7.8 mg/l in post monsoon season. Lowest concentration of DO was found in ground water sample of Udhna Gam (3.2 mg/l, 2.9 mg/l, 3.28 mg/l in winter, summer and post monsoon season, respectively) and highest concentration of DO was found in ground water sample of Bhestan (7.4 mg/l, 7.3 mg/l, 7.8 mg/l in winter, summer and post monsoon season, respectively).

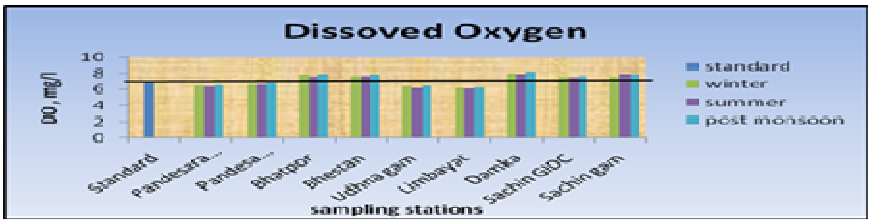

Figure 2: Graphical Representation for DO in Ground Water Sample

Chemical Oxygen Demand

The variation in COD data for all the studied 09 sampling stations is shown in figure 3 and the range of desirable limit for COD (according to International Standards, USEPA) of water prescribed for drinking purpose by International standard is 10 mg/l. COD should not be present in drinking water. The COD of all studied 09 ground water samples was found in the range of 100-410 mg/l in winter season, 120-420 mg/l in summer season and 90-390 mg/l in post monsoon season. In all ground water samples, COD concentration was found above desirable limit. Highest concentration of COD was found in Udhna Gam ground water sample (410 mg/l, 420 mg/l, 390 mg/l in winter, summer post monsoon season respectively). This is due to the industrial activity like Textile Dyeing and Printing industries, Metal Industries, Pharmaceutical industries and Chemical Industries running in Udhna Gam.

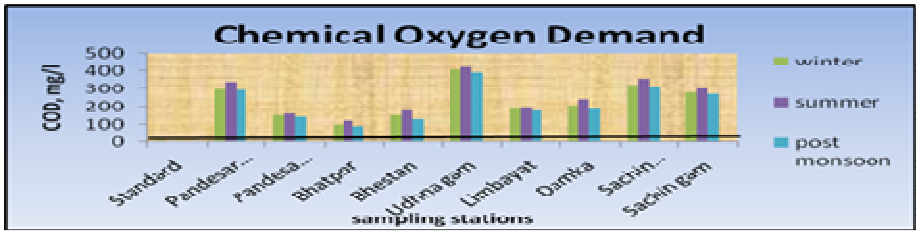

Figure 3: Graphical Representation for COD in Ground Water Samples

TSS, TDS, EC and Salinity

The variation in **TSS, TDS, EC and salinity** data for all the studied 09 sampling stations is shown in figure 4, figure 5, figure 6, figure 7 respectively and the range of desirable limit for TSS, TDS, EC and Salinity of water prescribed for drinking purpose by IS: 10500 are 100 mg/l, 1000 mg/l, 0.75 mS/cm and 0.5-1% ppt respectively. The TSS of all the studied 09 ground water samples was found in the range of 89-700 mg/l in winter season, 95-725 mg/l in summer season and 83-692 mg/l in post monsoon season. The TDS of all the studied 09 ground water samples was found in the range of 710-4200 mg/l in winter season, 725-4249.23 in summer season and 708-4115 mg/l in post monsoon. The EC of all the studied 09 ground water samples was found in the range of 1.1-6.8 mS/cm in winter season, 1.1-6.9 mS/cm in summer season 0.9-6.79 mS/cm in post monsoon season. The Salinity of all the studied 09 ground water samples was found in the range of 0.3-3.4 %ppt. in winter season, 0.4-3.4 % ppt. in summer season 0.3-3.33 %ppt. in post monsoon season. In all the studied 09 ground water samples (except Damka and Limbayat), TSS and TDS were found were found above desirable limit. TSS and TDS were found highest in Sachin Gam and Udhna Gam ground water sample respectively (TSS of Sachin Gam: 700 mg/l, 725 mg/l and 692 mg/l in winter, summer and post monsoon season respectively. TDS of Udhna Gam: 4200 mg/l, 4249.23 mg/l and 4115 mg/l in winter, summer and post monsoon season respectively). In all the 09 studied ground water samples (except Bhatpor and limbayat), EC and Salinity concentration were found above desirable limit. Highest concentration of EC was found in Sachin Gam ground water sample (EC: 6.8 mS/cm, 6.9 mS/cm, 6.79 mS/cm in winter, summer and post monsoon season respectively. Highest concentration of Salinity was found in ground water sample of Sachin Gam (Salinity: 3.4 %ppt., 3.4 %ppt., 3.33 %ppt. in winter, summer and post monsoon season respectively). The Electric Conductivity, Salinity and TDS are inter-related. [7, 8] EC is doubled of Salinity. The presences of current carrying ions are responsible for EC. The large variation in EC is mainly due to lithologic composition and anthropogenic activities prevailing in this region. Increasing the soluble minerals along flow path, groundwater movement through salt and evaporation are the major causes of salination in the industrial area. Gastro intentional irritation may increase due to high level of TDS. [6]

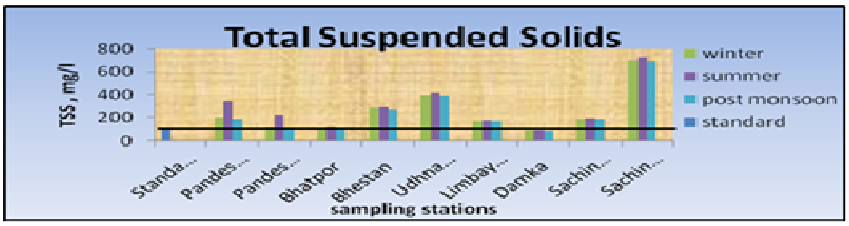

Figure 4: Graphical Representation for TSS in Ground Water Samples

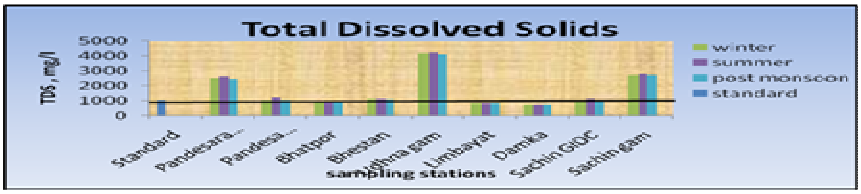

Figure 5: Graphical Representation for TDS in Ground Water Samples

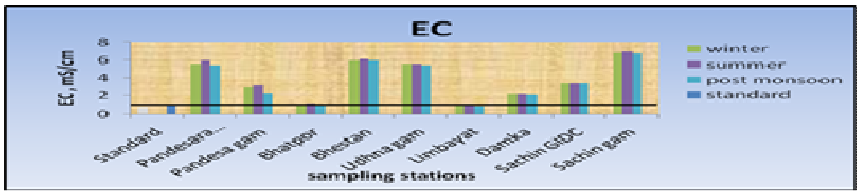

Figure 6: Graphical Representation for EC in Ground Water Samples

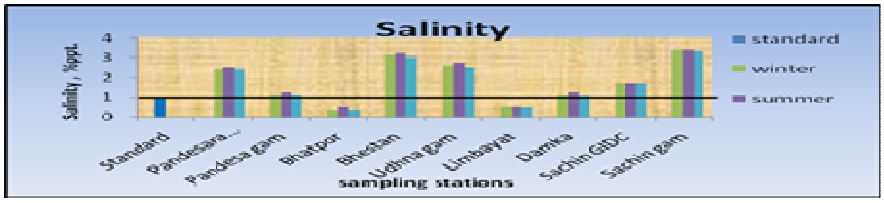

Figure 7: Graphical Representation for Salinity in Ground Water Samples

Total Hardness

The variation in Total Hardness data for all the studied 09 sampling stations is shown in figure 8 and the range of desirable limit for Hardness of water prescribed for drinking purpose by IS: 10500 is 300 mg/l. The Hardness of all the studied 09 ground water samples was found in the range of 495-1339 mg/l in winter season, 500-1400 mg/l in summer season and 480-1300 mg/l in post monsoon season. In all ground water samples, Total Hardness was found above desirable limit may be due to the presence of Calcium, Magnesium, Chloride and Sulphate ion in Water. [7] Highest Total Hardness was found in groundwater sample of Udhna Gam (1339 mg/l, 1400 mg/l, 1300 mg/l in winter, summer and post monsoon season respectively). The Total Hardness is relatively high (above desirable limit) in all samples Hardness is the permanent feature of ground water quality of Surat City.

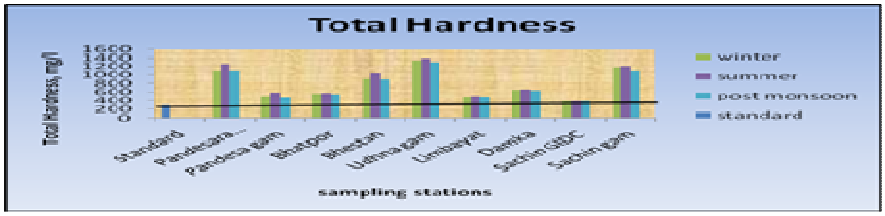

Figure 8: Graphical Representation for Total Hardness in Ground Water Samples

Ca and Mg Hardness

The variation in Calcium and Magnesium Hardness data for all the studied 09 sampling stations are shown in figure 9 and figure 10 and the range of desirable limit for Ca and Mg Hardness of water prescribed for drinking purpose by IS: 10500 is 75 mg/l and 30 mg/l respectively. The Ca Hardness of all the studied 09 ground water samples was found in the range of 120-400 mg/l in winter season, 130-450 mg/l in summer season and 118-380 mg/l in post monsoon season. The Mg Hardness of all the studied 09 ground water samples was found in the range of 335-1091 mg/l in winter season,

330-1150 mg/l in summer season and 235-1065 mg/l in post monsoon season. In all ground water samples Ca and Mg Hardness were found above desirable limit. Ca Hardness was found higher in ground water sample of Pandesara housing colony (400 mg/l, 450 mg/l and 350 mg/l in winter, summer and post monsoon season respectively). Mg Hardness was found higher in ground water sample of Udhna Gam (1091 mg/l, 1150 mg/l and 1065 mg/l in winter, summer and post monsoon season, respectively). The presence of Calcium in the groundwater is may be due to Calcium mineral group, such as pyroxene and amphibole in the igneous rocks. In all the samples Mg Hardness was obtained because the Magnesium in ground water may derived from dissolution of Magnesium Calcite, Gypsum and Dolomite from source rocks. [7]

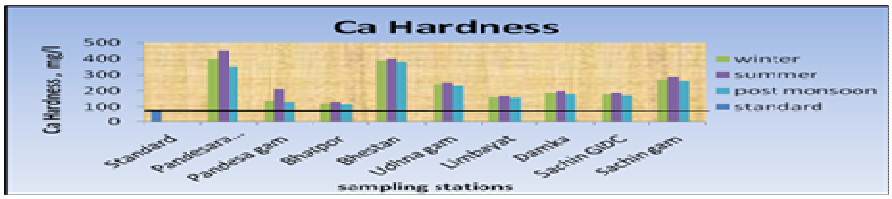

Figure 9: Graphical Representation for Ca Hardness in Ground Water Samples

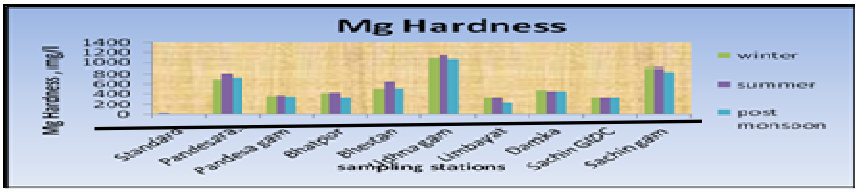

Figure 10: Graphical Representation for Mg Hardness in Ground Water Samples

Copper

The variation in Copper data for all the studied 09 sampling stations is shown in figure 11 and the range of desirable limit for Copper of water prescribed for drinking purpose by IS: 10500 is 0.05 mg/l. The Copper of all the studied 09 ground water samples was found in the range of 2.3-93.2 mg/l in winter season, 2.38-95.31 mg/l in summer season and 2.25-93.0 mg/l in post monsoon season. In all ground water samples Copper concentration was found above desirable limit. Highest concentration of Copper was found in Udhna Gam ground water sample (93.2mg/l, 93.31mg/l, 93mg/l in winter, summer, post monsoon season respectively). The metal industry which manufacture and provide service for Copper strip, Copper product, Copper metal, Copper flat located nearer to Udhna Gam may be the responsible for high concentration of Copper found in Udhna Gam groundwater sample. Consumption of high levels of Copper can cause nausea, vomiting, diarrhea, gastric complaints and headaches. Long term exposure over many months and years can cause liver damage and death. [8, 9]

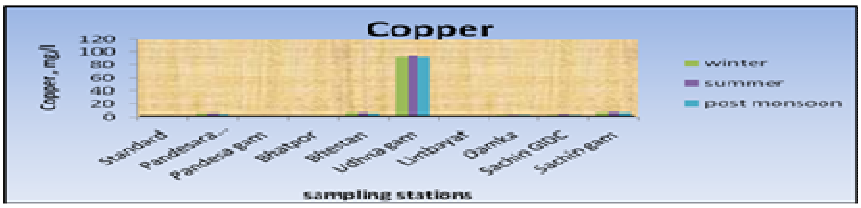

Figure 11: Graphical Representation for Copper in Ground Water Samples

Zinc

The variation in Zinc data for all the studied 09 sampling stations is shown in figure 12 and the range of desirable limit for Zinc of water prescribed for drinking purpose by IS: 10500 is 5 mg/l. The Zinc of all the studied 09 ground water

samples was found in the range of 1.2-192 mg/l in winter season, 1.22-195 mg/l in summer season and 1.1-191 mg/l in post monsoon season. In ground water sample of Pandesara housing colony, Bhatpor, Udhna Gam, Limbayat, Damka and Sachin GIDC, Iron concentration was found above desirable limit. Highest concentration of Zinc was found in Udhna Gam ground water sample (192 mg/l, 195 mg/l, 191 mg/l in winter, summer, post monsoon season respectively). The chemical industries which manufacture Zinc and other metal related chemicals located in Udhna GIDC may be responsible for high concentration of Zinc in Udhna Gam ground water samples. Generally, Zn is an essential plant and human nutrient for metabolism, yet Zinc causes astringent taste and opalescence in water. [9, 10]

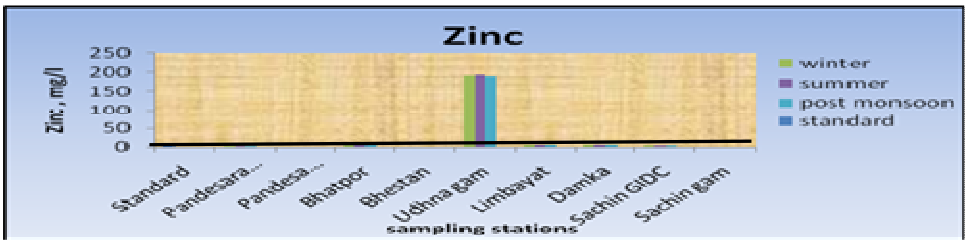

Figure 12: Graphical Representation for Zinc in Ground Water Samples

Iron

The variation in Iron data for all the studied 09 sampling stations is shown in figure 13 and the range of desirable limit for Iron of water prescribed for drinking purpose by IS: 10500 is 0.3 mg/l. Iron of all the studied 09 ground water samples was found in the range of 0.06-0.7 mg/l in winter season, 0.07-0.88 mg/l in summer season and 0.04-0.7 mg/l in post monsoon season. In ground water samples of Pandesra housing colony and Sachin GIDC, Iron concentration was found above desirable limit. (Pandesara housing colony: 0.7 mg/l, 0.82 mg/l, 0.7 mg/l in winter, summer and post monsoon season, respectively and Sachin GIDC: 0.79 mg/l, 0.8 mg/l, 0.7 mg/l in winter, summer and post monsoon season, respectively). Except these two stations in all ground water samples, Iron concentration was found within desirable limit. In present study the industrial activity (especially Iron related manufacturing metal industries) which is running nearer to these two stations is strong reason for high concentration of Iron in groundwater. High concentration causes slight toxicity, inky flavour, bitter and astringent taste of water. [11,]

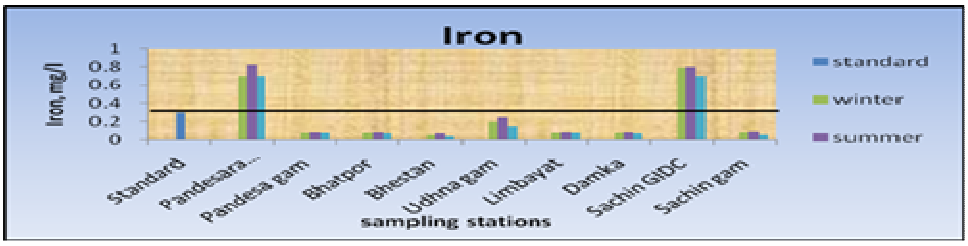

Figure 13: Graphical Representation for Iron in Ground Water Samples

Sodium and Potassium

The variation in Sodium and Potassium data for all the studied 09 sampling stations are shown in figure 14 and 15 and the range of desirable limit for Sodium and Potassium of water prescribed for drinking purpose by IS: 10500 are 75-200 mg/l and 12 mg/l respectively. The Sodium concentration of all the studied 09 ground water samples was found in the range of 70-240 mg/l in winter season, 75-250 mg/l in summer season and 69-210 mg/l in post monsoon season. The Potassium concentration of all the studied 09 ground water samples was found in the range of 39-56 mg/l in winter season,

40-57 mg/l in summer season and 38-53 mg/l in post monsoon season. In all the samples of ground water, Sodium concentration was found within desirable limit in all season. Highest concentration of Sodium in ground water sample of Udhna Gam (240 mg/l, 250 mg/l, 210 mg/l in winter, summer post monsoon season respectively). In all the samples of ground water, Potassium concentration was found above desirable limit in all season. Highest concentration of Potassium was found in ground water sample of Damka (56 mg/l, 57 mg/l, 53 mg/l in winter, summer, post monsoon season respectively). The high Sodium concentration makes the water unsuitable for domestic use because it causes severe health problems like hypertension. Therefore, Sodium restricted diet is suggested to the patients, who suffer from the heart diseases and also from the kidney problems. Sodium may derived from untreated industrial and domestic waste, weathering of feldspar rocks and also due to over exploitation of groundwater sources in this area. [6]**.** The higher amount of Potassium is observed may be due to fertilizer manufacturing industry and industries percolating alkaline untreated effluent directly into groundwater. The excess amount of potassium present in the water sample may lead nervous and digestive disorder. [12, 7]

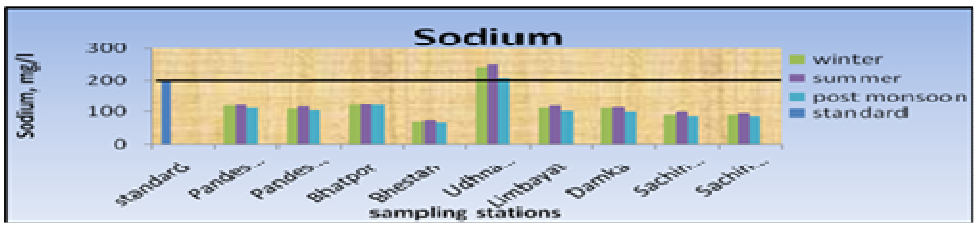

Figure 14: Graphical Representation for Sodium in Ground Water Samples

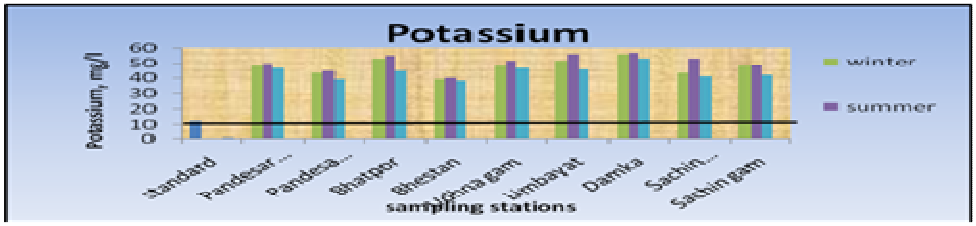

Figure 15: Graphical Representation for Potassium in Ground Water Samples

Ammonia

The variation in Ammonia data for all the studied 09 sampling stations is shown in figure 16 and the range of desirable limit for Ammonia of water prescribed for drinking purpose by IS: 10500 is 0.001 mg/l. The Ammonia of all the studied 09 ground water samples was found in the range of 0.02-0.05 mg/l in winter season, 0.04-0.08 mg/l in summer season and 0.015-0.049 mg/l in post monsoon season. In all the samples Ammonia concentration was found above desirable limit. Highest concentration of Ammonia was found in Pandesara housing colony and Udhna Gam (Pandesara housing colony: 0.05 mg/l, 0.08 mg/l, 0.049 mg/l in winter, summer, post monsoon season respectively Udhna Gam: 0.05 mg/l, 0.08 mg/l, 0.048 mg/l in winter, summer, post monsoon season respectively). The natural microbial biodegradation process and the Urea manufacturing industry may be the reason for high concentration of Ammonia in all ground water samples. High concentration of Ammonia may cause irritation of respiratory tracts, burning of skin, eye, throat and lungs. These burns might be serious enough to cause permanent blindness, lung diseases or death. [13, 14]

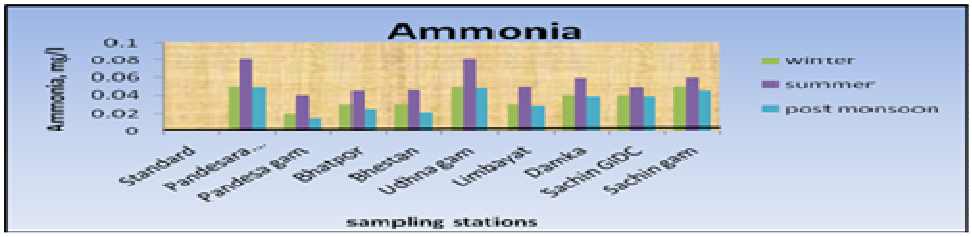

Figure 16: Graphical Representation for Ammonia in Ground Water Samples

Boron

The variation in Boron data for all the studied 09 sampling stations is shown in figure 17 and the range of desirable limit for Boron of water prescribed for drinking purpose by IS: 10500 is 1.0 mg/l. The Boron of all the studied 09 ground water samples was found in the range of 5.7-7.7 mg/l in winter season, 6.0-8.2 mg/l in summer season and 5.5-7.7 mg/l in post monsoon season. In all ground water samples Boron concentration was found above desirable limit. Highest concentration was found in ground water sample of Damka (7.7 mg/l, 8.2 mg/l and 7.7 mg/l in winter, summer and post monsoon season, respectively). Boron can be released from industries that use Boron or the Boron compound like leather tanning, cement works and the glass works (the glass and cement manufacturing industries are located in Pandesara GIDC, Udhna GIDC and Sachin GIDC). Health effects of Boron include nausea, abdominal pain, diarrhea, persistent vomiting which may be accompanied by headache, weakness, lethargy, restlessness etc. [11]

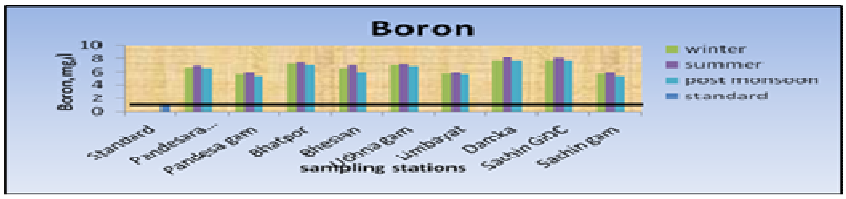

Figure 17: Graphical Representation for Boron in Ground Water Samples

Silica

The variation in Silica data for all the studied 09 sampling stations is shown in figure 18. The Silica in all the studied 09 ground water samples was found in the range of 42-132 mg/l in winter season, 60-148 mg/l in summer season, 38-120 mg/l in post monsoon season. Silica is mineral commonly found in ground water (14 mg/L), not easily dissolve in water but held in suspension. In all the samples, silica concentration was found above the desirable limit. Highest concentration of Silica was found in ground water sample of Limbayat (132 mg/l, 148 mg/l, 120 mg/l in winter, summer, post monsoon season respectively). The antifoaming agent Antimussol fki. Liq. for Dyeing application used in Textile and Dyeing industry may be the reason for high concentration of Silica in ground water samples. Silica is derived from weathering of Silicate minerals contained in the bed rocks. [15] The higher concentration of Silica can cause silicosis.

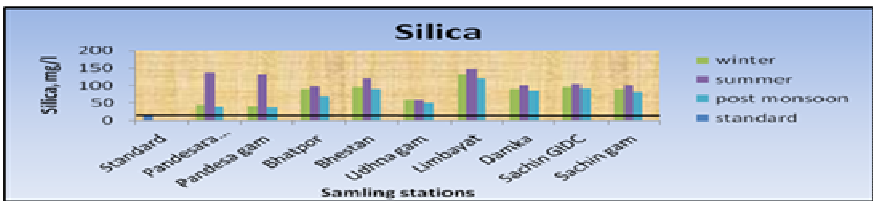

Figure 18: Graphical Representation for Silica in Ground Water Samples

Turbidity

The variation in Turbidity data for all the studied 09 sampling stations is shown in figure 19 and the range of desirable limit for Turbidity of water prescribed for drinking purpose by IS: 10500 is 5 NTU. The Turbidity of all the studied 09 ground water samples was found in the range from 0.89-2.8 NTU in winter season, 0.9-2.9 NTU in summer season and 0.87-2.79 NTU in post monsoon season. In all ground water samples, Turbidity was found within desirable limit. Highest concentration of Turbidity was found in ground water sample of Udhna Gam (2.8 NTU, 2.9 NTU and 2.79 NTU in winter, summer and post monsoon season, respectively). The presence of Suspended matters such as silt, clay, Silica, fine organic and inorganic matter, presence of microorganisms and the natural geology are responsible for causing Turbidity in the ground water. Turbidity above desirable limit causes health problems like nausea, cramps and diarrhea. [16, 17]

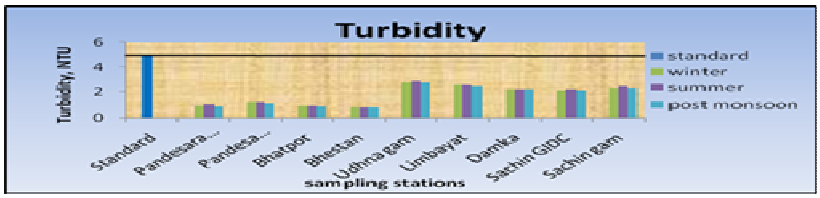

Figure 19: Graphical Representation for Turbidity in Ground Water Samples

Phenol:

The variation in Phenol data for all the studied 09 sampling stations is shown in figure 20 and the range of desirable limit for Phenol of water prescribed for drinking purpose by IS: 10500 is 0.001 mg/l. The phenol of all the studied 09 ground water samples was found in the range of 0.48-3.49 mg/l in winter season, 0.49-3.6 mg/l in summer season and 0.4-3.5 mg/l in post monsoon season. Out of 9 ground water samples, in ground water samples of Pandesara housing colony, Bhatpor, Bhestan, Udhna Gam and Limbayat, Phenol concentration was found above desirable limit. In ground water samples of Pandesara Gam, Damka, Sachin GIDC, Sachin Gam, Phenol was not found. Highest concentration of Phenol was found in ground water sample of Udhna Gam (3.49 mg/l, 3.6 mg/l, 3.5 mg/l in winter, summer and post monsoon season respectively). The industry running nearer to Udhna Gam which manufactures Phenol formaldehyde resin may be strong reason behind high concentration of Phenol. Phenol is rapidly absorbed through inhalation (wheezing, cough, dyspnoea), ingestion (gastrointestinal effects) and through the skin (inflammation, erythema). [11]

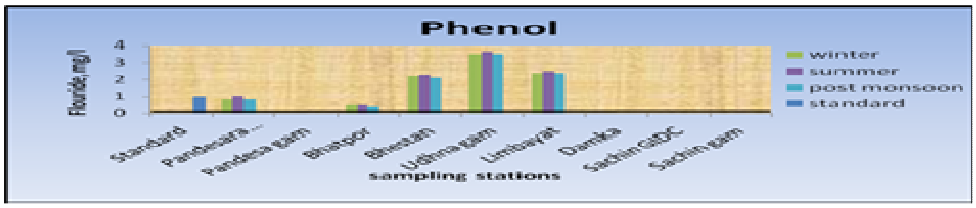

Figure 20: Graphical Representation for Phenol in Ground Water Samples

Chloride

The variation in Chloride data for all the studied 09 sampling stations is shown in figure 21 and the range of desirable limit for Chloride of water prescribed for drinking purpose by IS: 10500 is 250 mg/l. the Chloride of all the studied 09 ground water sample was found in the range of 115.5-1400 mg/l in winter season, 119.91-1419.57 mg/l in

summer season and 110-1329 mg/l in post monsoon season. In almost all the samples (except Bhatpor and Limbayat) Chloride was found above desirable limit. Highest concentration of Chloride was found in Udhna Gam ground water sample (1400 mg/l, 1419.57 mg/l, 1329 mg/l in winter, summer, post monsoon season respectively). Chloride is widely distributed in all types of rocks in one or the other form. Chloride imparts a salty taste and some times higher consumption causes the crucial condition for the development of hypertension, risk for stroke, left ventricular hypertension, osteoporosis, renal stones and asthma in human beings. [7]

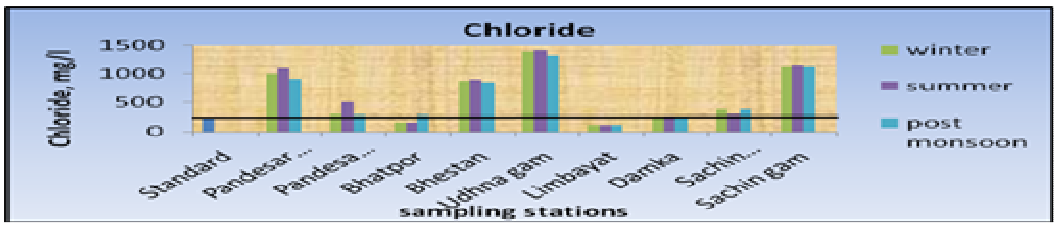

Figure 21: Graphical Representation for Chloride in Ground Water Samples

Fluoride

The variation in Fluoride data for all the studied 09 sampling stations is shown in figure 22. and the range of desirable limit for Fluoride of water prescribed for drinking purpose by IS: 10500 is 0.6-1.2 mg/l. Fluoride in all the studied 09 ground water samples was found in the range of 0.18-1.5 mg/l in winter 0.2-1.6 mg/l summer season and 0.1-1.45 mg/l in post monsoon season. Except Udhna Gam ground water samples, Fluoride concentration was found below desirable limit. In Udhna Gam ground water sample, fluoride concentration was found highest and above desirable limit (1.5 mg/l, 1.6 mg/, 1.45 mg/l in winter, summer, post monsoon season respectively). The industrial activity which is running nearer to this station may be responsible for high concentration of Fluoride. [18] Here, the Flouride related manufacturing industry is located very nearer to Udhana Gam. Excess Fluoride may also lead to fluorosis that can result in skeletal damage. Clinical report indicate that adequate Calcium intake is directly associated with reduced risk of dental fluorosis. Vitamin C also safeguards against the risk. [18, 7]

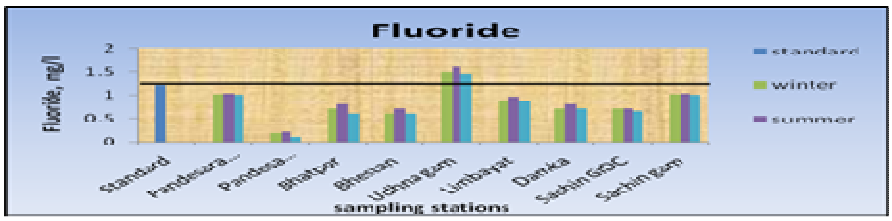

Figure 22: Graphical Representation for Fluoride in Ground Water Samples

Sulphate

The variation in Sulphate data for all the studied 09 sampling stations is shown in figure 23 and the range of desirable limit for Sulphate of water prescribed for drinking purpose by IS: 10500 is 200 mg/l. The Sulphate of all the studied 09 ground water samples was found in the range of 60-86 mg/l in winter season, 68-90 mg/l in summer season and 55-80 mg/l in post monsoon season. It is mainly derived from gypsum on oxidation of pyrites. [11] Highest concentration of Sulphate was found in ground water sample of Limbayat in winter and post monsoon season (86 mg/l and 80 mg/l in winter, summer and post monsoon season, respectively). Highest concentration of Sulphate was found in ground water sample of Udhna Gam in summer season (90 mg/l).The Sulphate (SO_4^{2-}) ion is one of the important anion present in

natural water produce catharsis, dehydration and gastrointestinal irritation effect upon human beings when it is present in excess of 200 mg/l, but in all the 09 samples of ground water samples, Sulphate concentration was found within desirable limit.

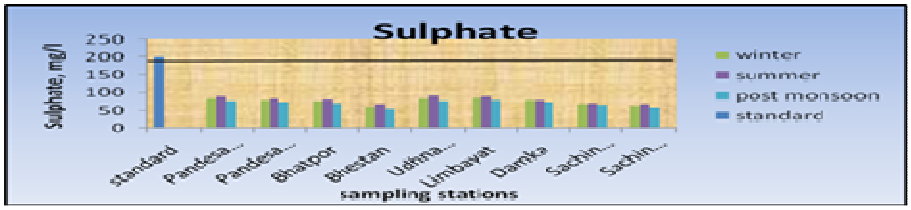

Figure 23: Graphical Representation for Sulphate in Ground Water Samples

Phosphate

The variation in Phosphate data for all the studied 09 sampling stations is shown in figure 24 and the range of desirable limit for Phosphate of water prescribed for drinking purpose by IS: 10500 is 0.02 mg/l. The Phosphate concentration of all the studied 09 ground water samples was found in the range of 0.4-0.6 mg/l in winter season, 0.5-0.7 mg/l in summer season and 0.33-0.59 mg/l in post monsoon season. In all the samples Phosphate concentration was found above desirable limit. Highest concentration of Phosphate was found in Sachin GIDC ground water sample in summer season (0.7 mg/l). The fertilizer industries manufacture fertilizer containing NPK, detergent manufacturing industry may be the reason for high concentration of Phosphate in groundwater. High concentration of phosphate can cause kidney damage and osteoporosis. [19]

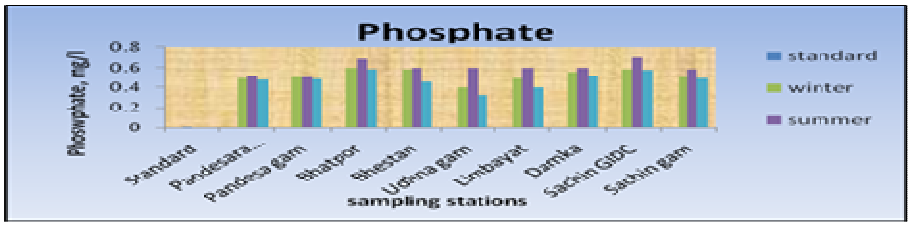

Figure 24: Graphical Representation for Phosphate in Ground Water Samples

Most Probable Number

The variation in MPN data for all the studied 09 sampling stations is shown in figure 25 and the range of desirable limit for MPN of water prescribed for drinking purpose by IS: 10500 is 0. The MPN of all the studied 09 samples was found in the range from 22-124 in winter season, 25-125 in summer season and 20-122 in post monsoon season. In all ground water samples MPN was found beyond desirable limit. In Udhna Gam (124, 125, 122 in winter, summer, post monsoon season respectively) and Limbayat (122, 123, 118 in winter, summer, post monsoon season respectively) ground water samples, MPN was found higher than other 7 stations. The MPN gives the indication for the presence of *E-coli* (Coliform bacteria) in ground water samples. E-coli may enter in ground water from sewage discharge, human or the animal waste. Generally the *E-coli* present in intestine of human and animal bodies which are harmless. But the infective strains of *E-coli* can enter into human and animal body through unhygienic food and polluted water which causes the illness like bloody diarrhea and fever. Two common waterborne diseases namely Giardiasis and Cryptosporidiosis (the intestinal illness) caused by the infective strain of *E-coli-0157:h7* [19]

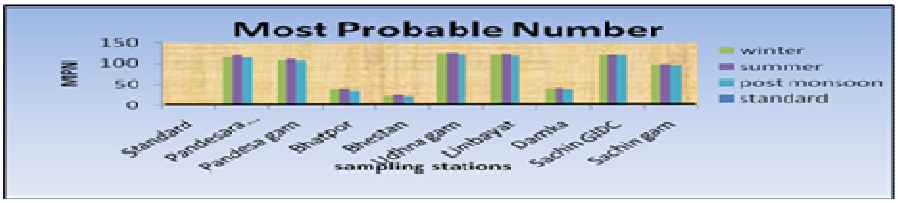

Figure 25: Graphical Representation for MPN in Ground Water Samples

Water Quality Index

The water quality index (WQI) gives the overall quality of water based on large number of physico-chemical characteristics of water. [20, 21] If the WQI value is <50 the quality of water considered as fit for human consumption, if WQI value is 50-80 the quality of water considered as moderately polluted, if WQI value is 80-100 excessive polluted the quality of water considered as excessively polluted, if WQI value is >100 the quality of water considered as severely polluted. The WQI value of all the studied 09 sampling stations have shown in **Table 2.** The graphical representation of WQI values of all the studied 09 sampling stations have shown in figure 26. All the stations were having high WQI values which show that all the stations are in severely polluted zone. The WQI values was found in the range of 179.82-1257.2 in winter season, 219.2-1290.11 in summer season, 167.42-1244.6 in post monsoon season.

Table 2: WQI Values of Ground Water Samples Nearer to Industrialized Area

Ranking of Sampling Stations According to WQI values	Sampling Stations	Winter	Summer	Post Monsoon	Average
1	Pandesara Gam	179.82	219.2	167.42	188.81
2	Bhatpor	197.03	225.54	190.86	204.47
3	Limbayat	220.75	238.08	207.39	220.07
4	Damka	257.28	255.11	253.5	255.29
5	Sachin GIDC	345.7	359.05	332.78	345.84
6	Bhestan	349.6	378.38	333.95	353.97
7	Sachin gam	388.96	405.79	376.74	390.49
8	Pandesara housing colony	399.52	430.97	388.8	406.43
9	Udhna Gam	1257.2	1290.11	1244.6	1263.97

Apart from all the stations, WQI values of Udhna Gam were very high (winter season: 1257.2, summer season: 1290.11, post monsoon season: 1244.6) because of high concentration of Chloride, Total Hardness, Ca Hardness, Mg Hardness, Fluoride, TSS, TDS, EC, Salinity, COD, Boron, Copper, Zinc, Fluoride, Silica, Phenol. Udhna Gam is very nearer to the Udhna GIDC (which are having 700 large scale and 6000 small scale industries of textile, chemical, pharmaceutical and metal industries) and the Udhna Khadi is 1.0-1.5 km away from the sampling point into which effluents of industries are discharged. The rank is given here in table 2, reflects the quantum of pollutants presence in ground water making it deteriorating and very poor quality. WQI values were found around range of 400-300 for ground water samples of Pandesara housing colony, Sachin Gam Bhestan and Sachin GIDC, and WQI values were found around range of 250-150 for Damka, Limbayat, Bhatpor and Pandesara Gam.

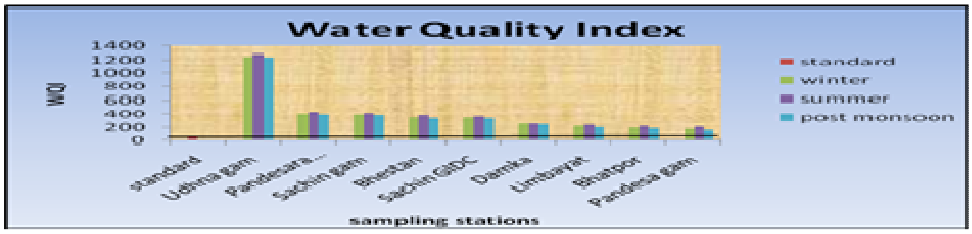

Figure 26: Graphical Representation for WQI

CONCLUSIONS

According to SAR value, all the ground water samples are in lower hazard category but according to range of WQI, it was found that all above listed 09 stations are in severely polluted zone. So none of the above listed groundwater sources can be used for drinking, industrial, domestic or for any other purpose. The values of each parameter, SAR and WQI obtained were relatively lower in winter, higher in summer and more lower in post monsoon season- indicating seasonal variation in ground water quality due to charging of water table and aquifers. As water table is charged in monsoon season the value of each parameter is lower in post monsoon season, in winter it becomes higher and in summer due to drying of water table as temperature rise the value of each parameter becomes much higher making the pollutants more concentrated. While due to monsoon water charging, in post monsoon season, pollutants in ground water were getting diluted. In winter the concentration of pollutants were found in between these two summer and post monsoon season. Because of industrial development, illegal discharge of drainage system, and solid waste dumping, khadi water is being highly polluted and therefore many local areas have experienced significant ground water contamination, which is cause of special concern. The Udhna Gam is very nearer to the Udhna khadi and this could be the reason for the high concentration of pollutants of Udhna Gam ground water sample, having highest WQI values in each season.

RECOMMENDATION

Preventive measures should be taken to minimize ground water pollution by bring to an end the ghost connection which are in industrialized zone. Every industry must treat its effluents at ETP level before discharge into water resources. The groundwater should be recharged regularly in every monsoon season by rain water harvesting in industrial area to improve water quality.

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